The Finite Element Analysis for Shot Peening Process of 20 Balls

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***Abstract*—Shot peening process is one of the widely adopted surfaces strengthening technology in the factory. It has some advantages and disadvantages compared with other processes (casting, welding, stamping, etc.). For example the advantages of the shot peening process: the process has the simple equipment, low cost of doing, not restricted by the shape and location of the parts, easy operation, etc. And the disadvantage is the poor operation condition ([1], [2], [3]).**

Index Terms*—Shot peening process, Finite element analysis, *Python script, Residual stress, Random impact model

I. Introduction

The finite element analysis (FEA) is a method which uses the mathematical approximation method to simulate the real physical system (geometry and loading conditions). And based on the simple and interacting elements which are called unit can use a limited number of unknown variables to approach the infinite unknown quantity of the real system. With time, the engineer has developed so many finite element software which can be used at some areas, and we can use the finite element to do simulation which can see the condition after the stress and others boundary conditions.

Firstly we use the intrinsic component in ABAQUS to do the simulation and find that the intrinsic component is difficult for the definition of the boundary conditions. Because of the distributed arrangements and sequences are predetermined by an intrinsic component which is far from the random impact model in actual production. I need to get the random impact model we developed a random impact model by python language in ABAQUS, and run the script ([4], [5], [6]).

II. The Background and Purpose of This Paper

A. The Background Of Shot Peening Process

Shot peening process is widely used to improve the mechanical strength, wear resistance, fatigue resistance and corrosion resistance of the parts. And also used to surface extinction, to scale, and eliminate the residual stress of casting, forging, welding, etc. Fig.1 shows the equipment and operation of the shot peening process in the mechanical industry.

Figure 1. The equipment and operation of the shot peening process

III. The Limitation Of The Inherent Module For Shot Peening Analysis In Abaqus

A. The Material Property Of The Plate And Ball In Shot Peening Process

The material data of the plate and ball will input to ABAQUS. The mass density of the ball is 7.8e-9, the Young’s modulus is 210,000, and Poisson’s ration is 0.31. The type of the balls is discrete rigid which isn’t deformation during the simulation.

The mass density of the plate is 7.8e-9, the Young’s modulus is 210,522, and Poisson’s ration is 0.31. The type of the plate is deformable and Fig.2 shows the true stress-strain cure of this material. The section of plate and ball is solid and homogeneous.

Manuscript received February 1, 2018; revised May 21, 2018.

doi: 10.18178/joace.6.1.9-16

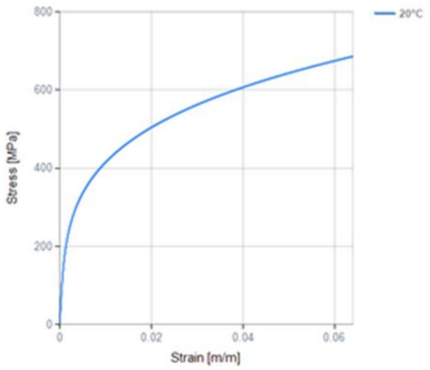


Figure 2. The property model in ABAQUS and true stress-strain cure of plate's material.

IV. The New Approach to Realize the Random Locations and Sequences of the Balls

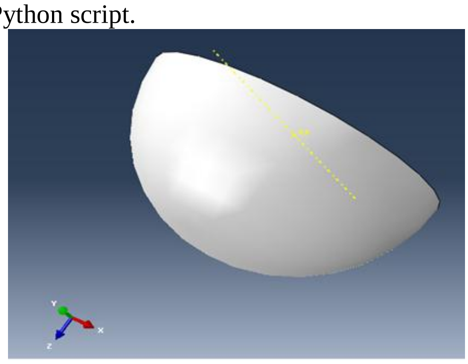
A. *The Application of Python Language In ABAQUS*

Python is an interpreted and object-orientation computer programming language which is invented in 1989 by Guido van Rossum. The grammar of the python is clear and concise, and an easy link with other various modules (especially C/C++) ([7], [8], [9], [10], [11], [12]). The design philosophy of the python is elegant, clear and simple. Python is easy to read compared with the other computer language. When we read the python script looks like read English. For the newcomer, python is easy to learn because of the very simple documentation.

We can use the python language to write the script. And after finishing the script run the script in ABAQUS that will automatic finish the process in ABAQUS. In this simulation, we will finish the modeling and material property of the plate and balls in ABAQUS in an inherent module. And the rest of the simulation the python script will finish.

B. *The Modeling And The Python Script For The Rest Steps (Assembly, Step, Interaction, Load, Mesh) In ABAQUS*

The multiple shot peening is based on two primary parts which are plate and balls. And Fig. 3 shows the modeling of the plate and ball in ABAQUS ([13], [14], [15]). The radius of the ball is 0.3mm, and the length of the square plate is 3mm. The modeling and the material property will be finished in ABAQUS inherent model, and the others balls will be automatically generate in latter Python script.



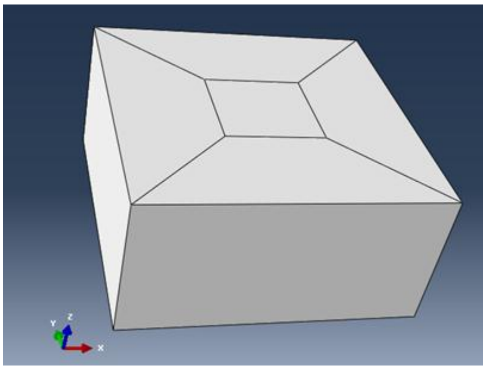


Figure 3. The modeling of square plate and ball in ABAQUS.

V. Results

We define 20 balls in the multiple shot peening, and have done four times. Every time every ball is random by the python script. Every time run the script we will get a different locations and sequences of the balls. It means that the residual stress of the strengthened layer. We get the value of the residual stress from different lines in the strengthened layer ([16], [17], [18]).

In post-processing two paths are defined to show the residual stress's value every time. The first path is (1368:976:-49, 40, 12313:12265:-1, 314, 3008, 3057, 3106, 3155, 3204, 3253, 3302, 3351, 3400) which is a middle line on the surface of the strengthened layer. And the second path is (12249, 12298, 12347, 38415, 38366, 38317, 38268, and 9946) which is a line perpendicular to the surface. Fig.4 and 5 shows the paths as follow ([19], [20], [21]):

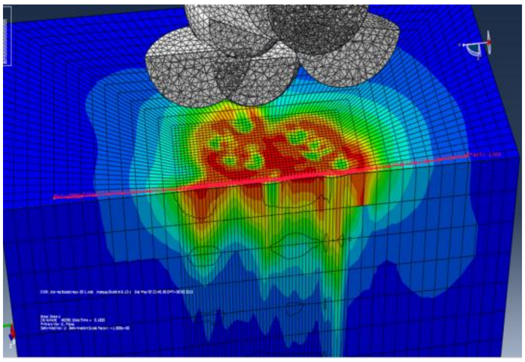


Figure 4. The horizontal path and the vertical path line.

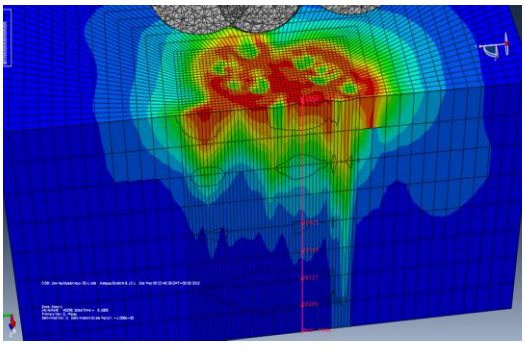
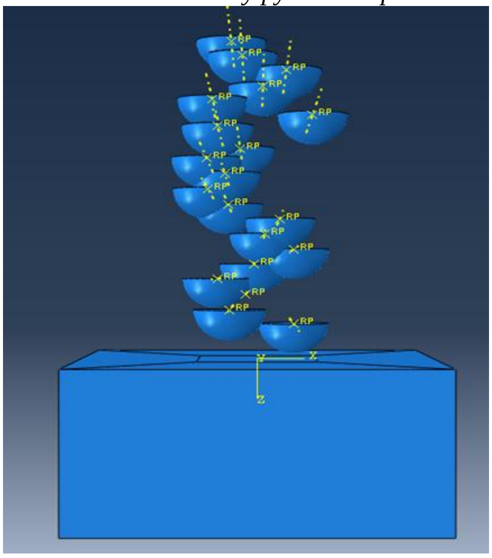


Figure 5. The horizontal path and the vertical path line.

The first simulation of 20 balls' sequences different times by python script



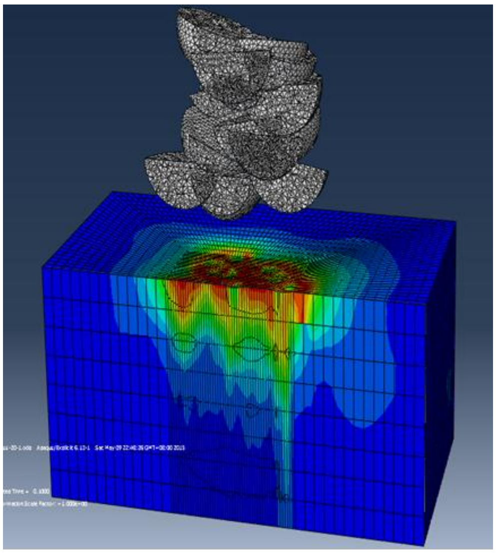


Figure 6. The first time arrangement and residual stress of shot peening process in ABAQUS.

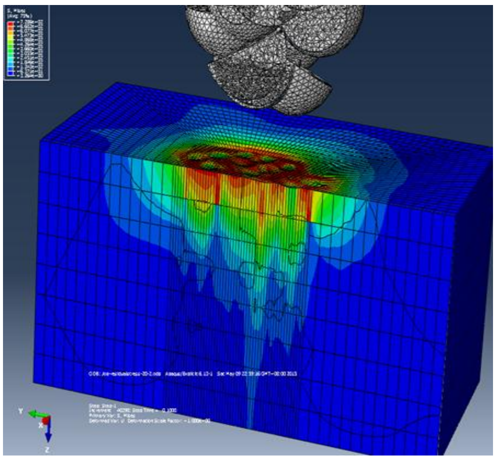


Figure 7. The second time arrangement and residual stress of shot peening process in ABAQUS.

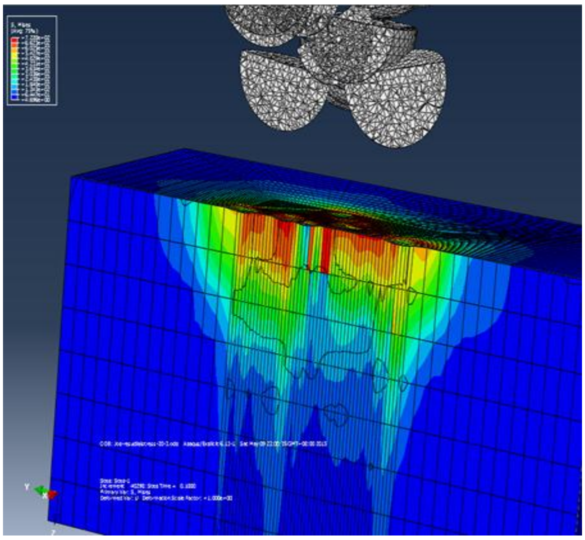


Figure 8. The third time arrangement and residual stress of shot peening process in ABAQUS.

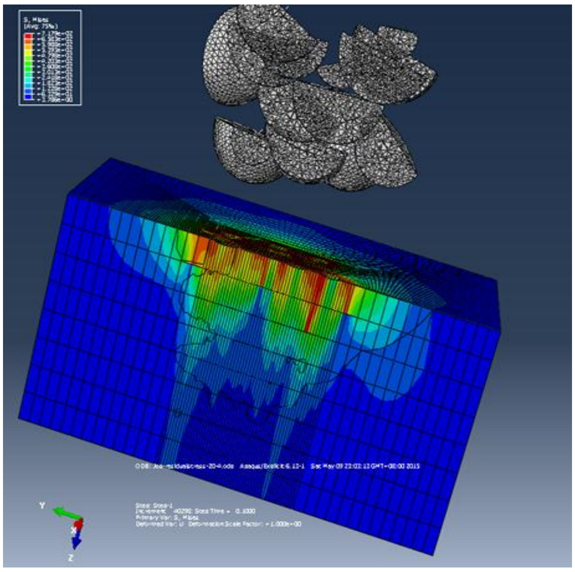


Figure 9. The fourth time arrangement and residual stress of shot peening process in ABAQUS.

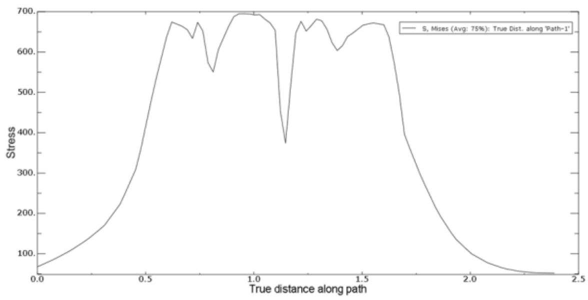


Figure 10. The residual stress curve of the horizontal path first time of 20 balls

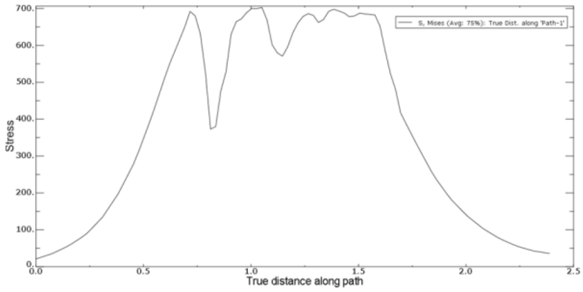


Figure 11. The residual stress curve of the horizontal path second time of 20 balls.

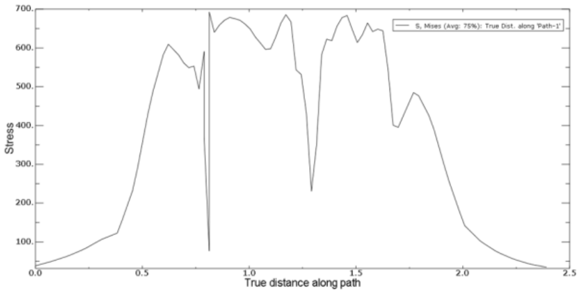


Figure 12. The residual stress curve of the horizontal path third time of 20 balls.

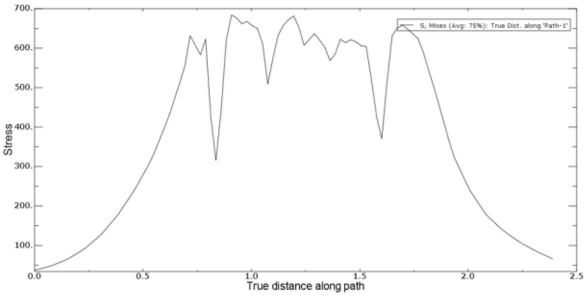


Figure 13. The residual stress curve of the horizontal path fourth time of 20 balls.

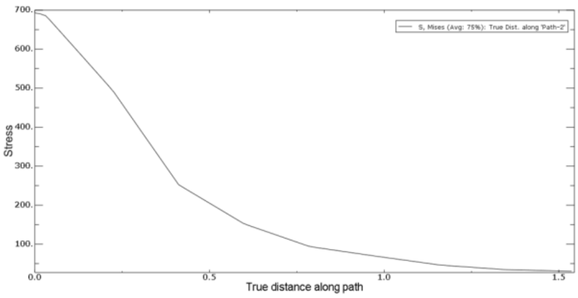


Figure 14. The residual stress curve of the vertical path first time of 20 balls.

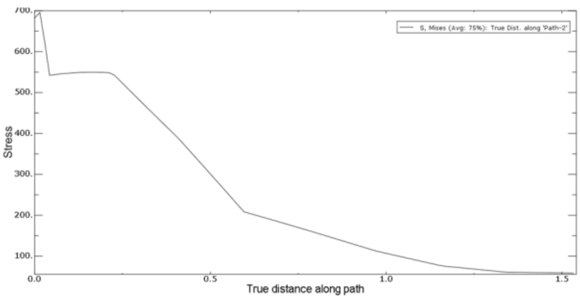


Figure 15. The residual stress curve of the vertical path second time of 20 balls

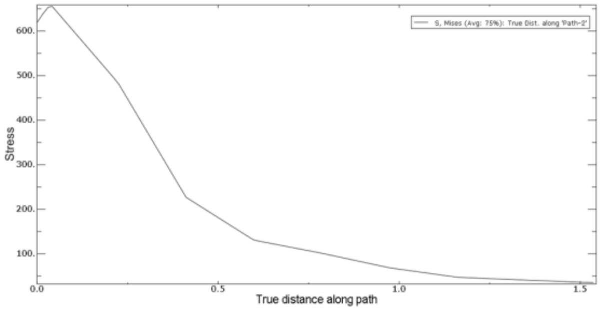


Figure 16. The residual stress curve of the vertical path third time of 20 balls.

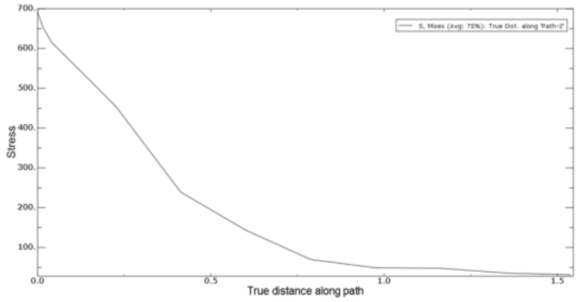


Figure 17. The residual stress curve of the vertical path fourth time of 20 balls.

TABLE I. THE RESIDUAL STRESS VALUE OF THE HORIZONTAL PATH FIRST TIME OF 20 BALLS.

X/ True distance	Y/ Residual stress
0	67.6511
0.159253	109.993
0.318507	176.652
0.477761	358.881
0.637013	670.869
0.795983	552.592
0.954624	695.008
1.11342	532.463
1.27184	673.538
1.43109	638.327
1.59034	670.553
1.74956	319.029
1.90881	152.706
2.06807	80.4592
2.22732	56.2398
2.38657	51.8525

TABLE II. THE RESIDUAL STRESS VALUE OF THE HORIZONTAL PATH SECOND TIME OF 20 BALLS.

X/ True distance	Y/ Residual stress
0	21.1595
0.15926	59.4037
0.318519	142.108
0.477778	312.769
0.637038	571.916
0.795655	477.995
0.953476	672.028
1.11241	585.561
1.27165	688.776
1.43091	688.058
1.59009	666.101
1.74933	353.257
1.90858	197.452
2.06784	107.68
2.2271	57.4019
2.38636	36.0959

TABLE III. THE RESIDUAL STRESS VALUE OF THE HORIZONTAL PATH THIRD TIME OF 20 BALLS.

X/ True distance	Y/ Residual stress
0	38.3798
0.159493	65.1515
0.318986	108.517
0.478479	291.863
0.637927	600.324
0.79674	692.627
0.79674	76.7709
0.955597	671.444
1.11508	614.346
1.27409	367.179
1.43272	678.089
1.59116	640.842
1.74942	465.013
1.90875	297.394
2.06824	107.139
2.22773	56.7534
2.38722	34.6575

TABLE IV. THE RESIDUAL STRESS VALUE OF THE HORIZONTAL PATH FOURTH TIME OF 20 BALLS.

X/ True distance	Y/ Residual stress
0	37.2336
0.159412	67.5747
0.318825	135.096
0.478237	257.293
0.63765	457.774
0.796773	565.664
0.955026	661.399
1.11403	626.164
1.27296	635.559
1.43237	613.837
1.59116	351.736
1.74999	632.063
1.9094	363.805
2.06881	186.837
2.22823	110.693
2.38764	65.9278

TABLE V. THE RESIDUAL STRESS VALUE OF THE VERTICAL PATH FIRST TIME OF 20 BALLS.

X/ True distance	Y/ Residual stress
0	693.115
0.0742013	619.499
0.176958	516.093
0.279714	390.676
0.38247	259.08
0.485226	200.099
0.587982	147.95
0.690739	116.058
0.793495	89.6965
0.896251	76.3173
0.999007	63.2534
1.10176	50.5385
1.20452	41.9347
1.30728	35.5472
1.41003	32.617
1.51279	30.421

TABLE VI. THE RESIDUAL STRESS VALUE OF THE VERTICAL PATH SECOND TIME OF 20 BALLS.

X/ True distance	Y/ Residual stress
0	682.001
0.0792384	547.65
0.181671	549.087
0.284103	476.734
0.386535	390.485
0.488967	292.45
0.591399	204.48
0.693831	178.998
0.796263	152.922
0.898695	126.102
1.00113	102.679
1.10356	82.7601
1.20599	70.2912
1.30842	61.6445
1.41086	59.3737
1.51329	58.402

TABLE VII. THE RESIDUAL STRESS VALUE OF THE VERTICAL PATH THIRD TIME OF 20 BALLS.

X/ True distance	Y/ Residual stress
0	618.798
0.0745089	601.932
0.177232	505.021
0.279956	374.069
0.382679	233.619
0.485402	176.653
0.588126	128.625
0.690849	112.586
0.793573	95.9102
0.896296	77.9731
0.999019	63.0522
1.10174	51.4478
1.20447	45.1783
1.30719	41.7688
1.40991	38.5477
1.51264	35.3664

TABLE VIII. THE RESIDUAL STRESS VALUE OF THE VERTICAL PATH FOURTH TIME OF 20 BALLS.

X/ True distance	Y/ Residual stress
0	692.077
0.0741004	565.466
0.17693	475.995
0.279759	364.449
0.382589	246.219
0.485418	189.782
0.588248	138.8
0.691077	98.3153
0.793906	66.3667
0.896736	54.9261
0.999565	48.5765
1.10239	47.9586
1.20522	43.5306
1.30805	37.0233
1.41088	33.8264
1.51371	56.7534

VI. SUMMARY AND CONCLUSIONS

An inclusive study has been performed on the definitions, requirements, theoretical, practical and eventually computational approaches that are available in the paper for the shot peening process. The following results can be drawn:

We are using the finite element analysis to do simulation in computer which can avoid the time and money consuming the process of trial and error. From the horizontal path we found three points, and saw the different values of the residual stress ([22], [23]). Three points are 0.159, 1.113, and 2.068 in the horizontal path. First point (0.159) the value of 20 balls' residual stress are 109.993, 59.4037, 65.1515, and 67.5747. The residual stress value of the second point is (1.113) and residual stress is 532.463, 585.561, 614.346, and 626.164. Third point residual stress values are 80.4592, 107.68, 107.139, and 186.837. And we also found three points in the vertical paths (0.17, 0.69, and 1.51). The values of residual stress of first point are (0.17) residual stress is 516.093, 549.087, 505.021, and 475.995. Second point (0.69) residual stress is 116.058, 178.998, 112.586, and 98.315. Third point (1.51) residual stresses are 30.421, 58.402, 35.366, and 56.753.

Because using the python script we can realize the random locations and arrangements of steel balls which are so closed to the experiment in factory. And from the finite element analysis simulation we can guide the actual production in the factory.

ACKNOWLEDGEMENT

This research was supported by the 2018 scientific promotion program funded by Jeju National University.

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